

What is claimed is:

1. In a charged-particle-beam (CPB) microlithography method in which a reticle, defining a pattern to be transferred to a sensitive substrate, is irradiated with a charged-particle illumination beam, and a charged-particle patterned beam,
5 formed by passage of the illumination beam through an illuminated portion of the reticle and carrying an aerial image of the illuminated portion of the reticle, is projected onto a sensitive surface of a substrate to imprint the sensitive surface with the aerial image, a method for evaluating imaging performance, comprising:
 - defining a beam-transmitting measurement mark at an object plane;
 - 10 defining a knife-edged reference mark, at an image plane, as a corresponding through-hole in a charged-particle-scattering membrane;
 - illuminating the measurement mark with a charged particle beam to form a charged-particle beamlet propagating downstream of the measurement mark toward the reference mark;
 - 15 projecting the beamlet onto the reference mark while scanning the beamlet over a knife-edge of the reference mark to produce non-scattered charged particles transmitted through the through-hole and forward-scattered charged particles transmitted through the membrane, the non-scattered and forward-scattered charged particles propagating downstream of the reference mark;
 - 20 disposing a beam-limiting diaphragm downstream of the reference mark, the beam-limiting diaphragm comprising a diaphragm plate defining a beam-limiting aperture having a diameter sufficient to block most of the forward-scattered charged particles while not blocking the non-scattered charged particles from reaching the detector; and
 - 25 detecting beam current of charged particles passing through the beam-limiting aperture.

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2. The method of claim 1, wherein the step of projecting the beamlet is performed using first and second projection lenses.

3. The method of claim 2, wherein an axial distance from the knife-
5 edged reference mark to the beam-limiting diaphragm is such that an axial angle of the beam-limiting aperture as measured at the knife-edge is slightly greater than a convergence angle of the beamlet at the substrate.

4. The method of claim 1, wherein:
10 the step of defining a measurement mark comprises defining multiple beam-transmitting measurement marks in a subfield of a reticle disposed at the object plane; and
the detecting step comprises detecting beam blur at multiple locations within the subfield.

15 5. The method of claim 1, wherein the step of defining the measurement mark comprises defining the measurement mark as a respective aperture in a reticle membrane.

20 6. The method of claim 5, wherein the measurement mark is defined as a respective aperture in a subfield of a reticle.

7. The method of claim 6, further comprising defining a dummy pattern around the measurement mark, as defined in a subfield of the reticle disposed at the
25 object plane.

8. The method of claim 7, wherein:

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as the measurement mark is illuminated with the charged particle beam, the charged particle beam illuminates the dummy pattern to produce at least one dummy beam propagating downstream of the measurement mark; and

the detection step comprises detecting beam blur of the beamlet attributable
5 to a space-charge effect resulting from the dummy beam.

9. The method of claim 1, wherein, in the step of defining the reference mark, the corresponding through-hole in the charged-particle-scattering membrane is provided with a rectangular profile.

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10. The method of claim 1, further comprising the step of disposing a second beam-limiting diaphragm downstream of the first beam-limiting diaphragm, the second beam-limiting diaphragm comprising a respective diaphragm plate defining a respective beam-limiting aperture, the respective diaphragm plate
15 blocking charged particles scattered by the charged-particle scattering membrane.

11. In a charged-particle-beam (CPB) microlithography apparatus for irradiating a reticle, defining a pattern to be transferred to a sensitive substrate, with a charged-particle illumination beam to form a charged-particle patterned beam,
20 formed by passage of the illumination beam through an illuminated portion of the reticle and carrying an aerial image of the illuminated portion of the reticle, that is projected onto a sensitized surface of a substrate, a device for evaluating imaging performance, comprising:

a beam-transmitting measurement mark situated at an object plane of the
25 CPB microlithography apparatus;

a knife-edged reference mark defined at an image plane as a corresponding through-hole in a charged-particle-scattering membrane;

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an illumination-lens assembly situated and configured to direct a charged particle beam at the measurement mark so as to form a charged-particle beamlet propagating downstream of the measurement mark toward the reference mark;

5 a projection-lens assembly situated and configured to project the beamlet onto the reference mark and to scan the beamlet over a knife-edge of the reference mark to produce non-scattered charged particles transmitted through the through-hole and forward-scattered charged particles transmitted through the membrane;

10 a beam-limiting diaphragm situated downstream of the reference mark, the beam-limiting diaphragm comprising a diaphragm plate defining a beam-limiting aperture that passes the non-scattered charged particles as the diaphragm plate blocks most of the forward-scattered charged particles; and

a detector situated and configured to detect a beam current of the charged particles propagating downstream of the beam-limiting diaphragm.

15 12. The device of claim 11, wherein the beam-limiting diaphragm is a first beam-limiting diaphragm, the device further comprising a second beam-limiting diaphragm situated between the first beam-limiting diaphragm and the detector, the second beam-limiting diaphragm comprising a respective diaphragm plate defining a respective aperture, the respective aperture being configured to pass the non-
20 scattered charged particles as the respective diaphragm plate blocks the forward-scattered charged particles.

25 13. In a charged-particle-beam (CPB) microlithography method in which a reticle, defining a pattern to be transferred to a sensitive substrate, is irradiated with a charged-particle illumination beam, and a charged-particle patterned beam, formed by passage of the illumination beam through an illuminated portion of the reticle, is projected onto a sensitive surface of a substrate to imprint the sensitive surface with the aerial image, a method for evaluating imaging performance, comprising:

defining a beam-transmitting measurement mark at an object plane;

defining a knife-edged reference mark, at an image plane, as a corresponding through-hole in a charged-particle-scattering membrane;

illuminating the measurement mark with a charged particle beam to form a
5 charged-particle beamlet propagating downstream of the measurement mark toward the reference mark;

projecting the beamlet onto the reference mark while scanning the beamlet over a knife-edge of the reference mark to produce non-scattered charged particles transmitted through the through-hole and forward-scattered charged particles
10 transmitted through the membrane, the non-scattered and forward-scattered charged particles propagating downstream of the reference mark;

using a detector situated downstream of the reference mark, detecting a beam current of charged particles propagating downstream of the reference mark; and

between the reference mark and the detector, selectively allowing the non-
15 scattered charged particles to propagate to the detector while blocking propagation of most of the forward-scattered charged particles to the detector.

14. The method of claim 13, wherein the excluding step comprises:

defining a beam-limiting aperture in a beam-limiting aperture plate; and

20 disposing the beam-limiting aperture plate between the reference mark and the detector such that the non-scattered charged particles pass through the beam-limiting aperture and most of the forward-scattered charged particles are blocked by the aperture plate.

25 15. The method of claim 14, wherein the projecting step is performed using a projection-lens system comprising a first projection lens and a second projection lens.

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16. The method of claim 15, wherein the beam-limiting aperture has a diameter such that an axial angle of the beam-limiting aperture as measured at the knife-edge is slightly greater than a convergent angle of the beamlet at the second
5 projection lens.

17. The method of claim 13, wherein the through-hole in the charged-particle-scattering membrane defining the knife-edged reference mark has a rectangular profile.
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18. In a charged-particle-beam (CPB) microlithography apparatus for irradiating a reticle, defining a pattern to be transferred to a sensitive substrate, with a charged-particle illumination beam to form a charged-particle patterned beam, formed by passage of the illumination beam through an illuminated portion of the
15 reticle and carrying an aerial image of the illuminated portion of the reticle, that is projected onto a sensitized surface of a substrate, a device for evaluating imaging performance, comprising:

a beam-transmitting measurement mark situated at an object plane of the CPB microlithography apparatus;
20 a knife-edged reference mark defined at an image plane as a corresponding through-hole in a charged-particle-scattering membrane, the reference mark being situated such that a charged-particle beamlet formed by passage of a charged particle beam through the measurement mark can be scanned over the reference mark to produce non-scattered charged particles passing through the reference mark and
25 forward-scattered charged particles passing through the membrane;

a beam-limiting diaphragm situated downstream of the reference mark, the beam-limiting diaphragm comprising a diaphragm plate defining a beam-limiting

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aperture that passes the non-scattered charged particles as the diaphragm plate blocks most of the forward-scattered charged particles;

a detector situated downstream of the beam-limiting diaphragm and configured to detect a beam current of the charged particles propagating downstream
5 of the beam-limiting diaphragm; and

beam-blur measurement means connected to the detector and configured to measure beam blur from detection data obtained by the detector.

19. The device of claim 18, wherein the beam-limiting diaphragm is a
10 first beam-limiting diaphragm, the device further comprising a second beam-limiting diaphragm situated between the first beam-limiting diaphragm and the detector, the second beam-limiting diaphragm comprising a respective diaphragm plate defining a respective aperture, the respective aperture being configured to pass the non-scattered charged particles as the respective diaphragm plate blocks the forward-
15 scattered charged particles.

20. The device of claim 18, wherein the beam-limiting diaphragm is situated 2-20 mm downstream of the knife-edged reference mark.

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